REMARKS

Reconsideration of the application, as amended, is respectfully requested.

On page 2 of the office action, the Examiner found that the oath or declaration was defective. A new oath or declaration made in compliance with 37 CFR 1.67(a) is being submitted herewith, bearing the signatures of both inventors. MPEP §602.02.

In reviewing the application, applicants have realized that the section identifier "SUMMARY OF THE INVENTION", which was present in draft versions of the writeup, is missing from the submitted specification. Applicants hereby request that the application be amended to add the section identifier to the top of page 5 of the specification, where it properly identifies applicants' summary of the invention, as required by 37 CFR §1.73.

Applicants have also requested entry of an amendment to the specifications to include the term "polytetrafluoroethylene" which is "better known by the trade name Teflon®." See Attachment 1.

On page 2 of the office action, the Examiner objected to the specification as failing to provide proper antecedent basis for "the tracer platform having a ballistic coefficient substantially equivalent to a shot pellet's ballistic coefficient as seen in claims 5 and 17." On page 5, ll, 12-13, the specification provides a proper antecedent basis for the claim language:

> "In accordance with the present invention a shotgun tracer shell comprises a tracer platform with a ballistic coefficient equivalent to that of the shot pellets with which it is used."

On page 3 of the office action, the Examiner rejected claims 5 and 17 under 35 USC §112, second paragraph. Applicant is attaching hereto as Attachment 2 portions of a treatise which includes a definition of the term "ballistic coefficient," along with a discussion of the variables. While the term is merely referred to in the application, a person skilled in the art of ballistics would readily understand that the "ballistic coefficient is a measure of how well a projectile can overcome air resistance and maintain flight velocity. . . . It is a number that . . . equals the sectional density of the projectile divided by its coefficient of form." The term as used in the specification refers to the fact that the weight, diameter, and shape of the integrated platform and tracer are chosen so that its ballistic coefficient is equivalent to that of the shot pellets with which it is used. In any event, applicant has amended claims 5 and 17 to delete the word "substantially."

The Examiner rejected claims 6 and 18 under 35 U.S.C. §112, second paragraph, stating that it is unclear what the "other metals or other plastics" are. Applicants have amended claims 6 and 18 in accordance with this rejection.

The Examiner rejected claims 6 and 18 under 35 U.S.C. §112, second paragraph, for including the trademarked term TEFLON in the claim. Applicants have amended claims 6 and 18 in accordance with this rejection to substitute the word "polytetrafluoroethylene" for the term Teflon®. If the specification cannot be amended to include the word "polytetrafluoroethylene," applicants request that the Examiner simply remove the word "Teflon" from claims 6 and 18.

On page 4, the Examiner rejected claims 1-2, 4, 8, 13-14, 16 and 20 under 35 U.S.C. §102(b) as being anticipated by US. Patent No. 1,887,990 to Brownsdon *et al.*

The invention disclosed in Brownsdon *et al.* is very different from the invention disclosed by the applicants. The Examiner has stated that applicants' "cylindrical tracer platform" is found at 6, 7, elements which Brownsdon actually identifies as the tracer pellet (6) and seat (7) (next to the perforation in the wad). Brownsdon's claim calls out "a tracer cartridge comprising a small cylinder open at one end and closed at the other . . . the open end . . . being seated upon the driving wad . . . the closed end of the said tracer cartridge being in engagement with the shot charge" (p. 2, ll. 4-12). Brownsdon notes that the tracer pellet "is positioned centrally at the base of the shot charge, and yet is substantially as free to move forward with the shot as the shot pellets themselves" (p. 1, ll. 22-26). "[T]he tracer pellet sits loosely in a central perforation in the wad which is immediately behind the charge of shot." (Col. 1, ll. 29-31). Tracers such as Brownsdon's are expected to travel with the shot simply by its loose placement in the wad behind the shot. In fact, Brownsdon's tracer does <u>not</u> travel with the shot in the barrel, but rather tends to accelerate at a higher rate than the shot since it is subjected to a different force resulting from a higher dynamic pressure due to the smaller diameter perforation in the wad used to ignite the tracer material. Dynamic pressure is defined by the formula:

$$Pd = d*(V^2) / 2$$

where Pd = dynamic pressure in Pascals; d = density of gases (Kg / m^3); and V = velocity of gases (in meters per second). In essence, dynamic pressure is proportional to the square of the velocity. In Brownsdon, as the expanding mass of gases from ignition tries to force its way through the small orifice, its velocity increases dramatically and proportionally to the ratio of the square of the shotgun bore diameter to the square of the

orifice diameter. The end result is that the tracer pellet, having a smaller mass and being subjected to higher force, smashes into the shot while in the barrel, causing unpredictable trajectories and poor accuracy down range.

Applicants' claimed invention shows a tracer platform which fills the space between the shot charge and the propellant, essentially replacing the wad and the gas seal of an ordinary shell. The lower end of the tracer platform has a cavity which acts as the gas seal. The tracer element, an integral part of the platform, fills a cylindrical coaxial cavity having a lower end at the bottom of the platform, <u>away</u> from the shot. The lower end of the platform is not "open" as is Brownsdon's. Instead, it is formed with a coaxial cylindrical cavity filled with the material constituting the tracer element. After ignition of the shell and expansion of the gases, the platform, with the tracer element, moves as a single unit.

Appellants have amended claims 1 and 13 to more clearly define the subject matter of their invention. The claims, as amended, are not anticipated by Brownsdon *et al.* and should be allowable. Claims 2, 4, 8, 14, 16, and 20, which depend therefrom, should be allowable as well.

On page 5 of the office action, the Examiner rejected claims 3 and 15 under 35 U.S.C. §103(a) as being unpatentable over Brownsdon *et al.* as applied to claim 2 or 13, and further in view of U.S. Patent No. 6,694,887 to Diller. Applicants have amended claim 1, upon which 2 depends, and claim 13, so that they are allowable over Brownsdon *et al.*; claims 3 and 15, therefore, are not obvious and should be allowable.

On page 5, the Examiner rejected claims 5 and 17 under 35 U.S.C. §103(a) as being unpatentable over Brownsdon *et al.* as applied to claim 1 or 13, and further in view of U.S.

Patent No. 3,262,390. Applicants have amended claims 1 and 13, upon which claims 5 and 17, respectively, depend, so that they are allowable over Brownsdon *et al.* Therefore, claims 5 and 17 are not obvious, and should be allowable.

On page 6, the Examiner rejected claims 6 and 18 under 35 U.S.C. §103(a) as being unpatentable over Brownsdon *et al.* as modified by Cowles *et al.* as applied to claim 5 or 17, and further in view of U.S. Patent No. 6,694,887. Applicants have amended claims 6 and 18, upon which claims 6 and 18, respectively, depend, so that they are allowable over Brownsdon *et al.* Therefore, claims 6 and 18 are not obvious, and should be allowable.

On page 6, the Examiner rejected claims 7 and 19 under 35 U.S.C. §103(a) as being unpatentable over Brownsdon *et al.* as applied to claim 1 or 13, and further in view of U.S. Patent No. 4,841,866. Applicants have amended claims 1 and 13, upon which claims 7 and 19 respectively, depend, so that they are allowable over Brownsdon *et al.* Therefore, claims 7 and 19 are not obvious, and should be allowable.

On page 7, the Examiner rejected claims 9 and 21 under 35 U.S.C. §103(a) as being unpatentable over Brownsdon *et al.* as applied to claim 1 or 13, and further in view of U.S. Patent No. 1,887,989. Applicants have amended claims 1 and 13, upon which claims 9 and 21, respectively, depend, so that they are allowable over Brownsdon *et al.* Therefore, claims 9 and 21 are not obvious, and should be allowable.

On page 7, the Examiner rejected claims 9 -12 and 21-24 under 35 U.S.C. §103(a) as being unpatentable over Brownsdon *et al.* as applied to claim 1 or 13, and further in view of U.S. Patent No. 6,694,887. Applicants have amended claims 1 and 13, upon which claims 9 -12 and 21-24, respectively, depend, so that they are allowable over Brownsdon

et al. Therefore, claims 9-12 and 21-24 are not obvious, and should be allowable.

In light of the foregoing arguments, and upon entry of the amendments, allowance of claims 1 through 24 should be in order and is respectfully requested.

Date: February 25, 2005

Respectfully submitted,

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ATTACHMENTS

cc: Mr. James Dunnam
Mr. Mauricio Quintana

C:\A&G\Patents\dunnam\amdmt2

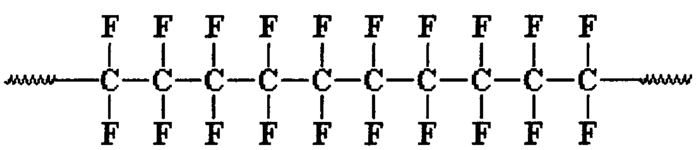
Polytetrafluoroethylene

$$-\!\!\left[CF_2 - CF_2 \right]_n\!\!-$$

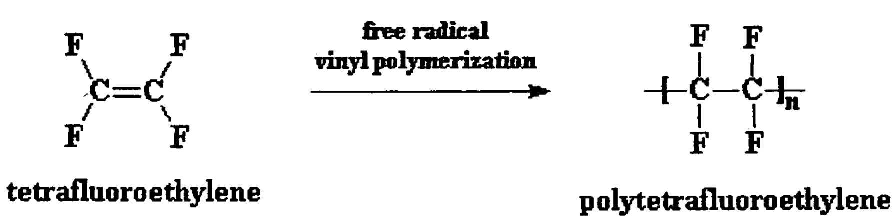
For polytetrafluoroethylene at a glance, click here!

Polytetrafluoroethylene is better known by the trade name Teflon®. It is used to make non-stick cooking pans, and anything else that needs to be slippery or non-stick. PTFE is also used to treat carpets and fabrics to make them stain resistant. What's more, it's also very useful in medical applications. Because human bodies rarely reject it, it can be used for making artificial body parts.

Polytetrafluoroethylene, or PTFE, is made of a carbon backbone chain, and each carbon has two fluorine atoms attached to it. It's usually drawn like the picture at the top of the page, but it may be easier to think of it as it's drawn in the picture below, with the chain of carbon atoms being thousands of atoms long.



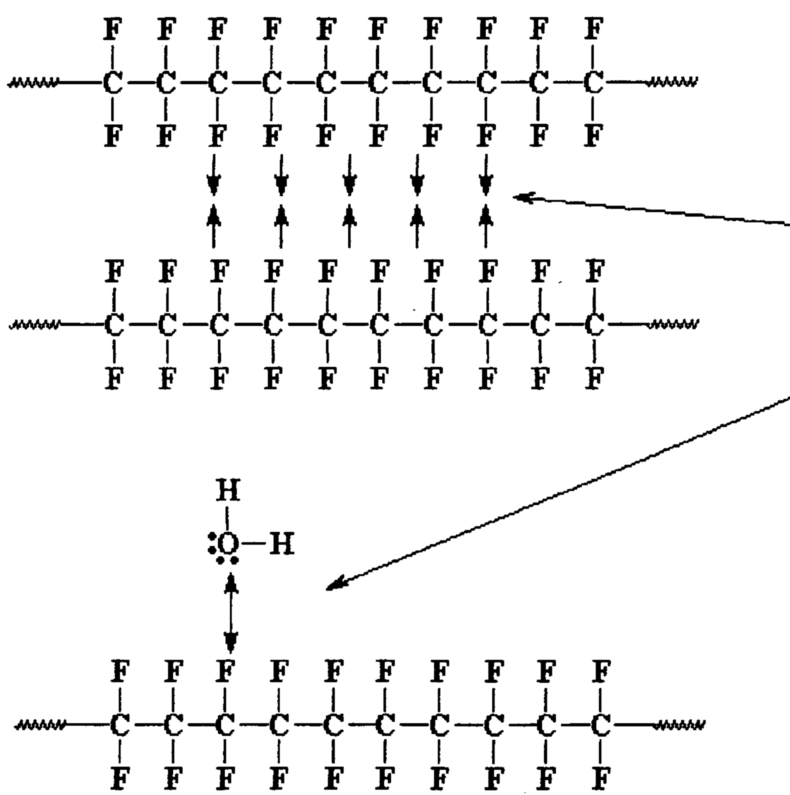
PTFE is a vinyl polymer, and its structure, if not its behavior, is similar to polyethylene. Polytetrafluoroethylene is made from the monomer tetrafluoroethylene by free radical vinyl polymerization.



And for those of you who are wondering, the monomer tetrafluoroethylene looks like this:

ATTACHMENT 1

Fluorine is a very strange element. When it is part of a molecule, it doesn't like to be around other molecules, even the fluorine atoms on other molecules. But it likes other kinds of molecules even less. So a molecule of PTFE, being just chock full of fluorine atoms as it is, would like to be as far away from other molecules as it can get. For this reason, the molecules at the surface of a piece of PTFE will repel the molecules of just about anything that tries to come close to it. This is why nothing sticks to PTFE.



The fluorine atoms of PTFE prefer their own kind, drawing to each other, while repelling any other kind of molecule, like this water molecule, for example.

Because it's non-stick, PTFE means you can fry things without grease or butter. This means less fat and cholesterol, for a healthier heart.

Enter Our Fun Contest!

The question remains then: If nothing will stick to this stuff, how does it stick to the surface of the frying pan? DuPont knows, but they're not telling!

So what do you think? If you were designing frying pans, and you had to make non-stick PTFE stick to frying pans, how would you do it? If any of you cyber fiends out there have any ideas about how DuPont gets Teflon® to stick to frying pans, we'd love to hear 'em!

Write down your idea on the form below and send it to us! If we like your idea enough, we'll post it on a special page devoted to your ideas. (And here's a hint: melting PTFE doesn't help. First, because you'd have to heat it to over 300 ^{o} to melt it, which is impractical for making something cheap like frying pans. Second, melting PTFE doesn't make it stickier. It just turns form a solid that nothing sticks to into a molten goo that nothing sticks to. And a third hint, roughening the surface of the pan won't help, either, because that only increases the area of the two surfaces which will repel each other, increasing the repulsive force.)

What's your name? (optional)
Organization? (optional)
Please inform us of your e-mail address. (optional)

Send Clear

How to be Inert

PTFE is more than just slippery. It's also useful because it won't react with anything. Why, you ask? First of all, if it repels everything, then no molecule can get near it to react with it! PTFE is kind of like a sad person who tries protect him or herself from emotional pain by never opening up to anyone.

Then there is the fact that the bond between the fluorine atom and the carbon atom is just really, really strong. The bond is almost bullet proof! It's so stable that nothing will react with it. Even when it gets as hot as a frying pan, not even oxygen will react with it!

Whoops!

Polytetraflouroethylene is another of those amazing accidental discoveries of science. In the late 1930s, when PTFE was discovered in DuPont's laboratories, DuPont was not at all concerned with nonstick frying pans or artificial heart valves. What they were really interested in was refrigeration. At the time, refrigerators used things like ammonia and sulfur dioxide as refrigerants. These are pretty nasty things to have leaking out of your refrigerator and into your kitchen. The quest was on, then, to make a non-toxic refrigerant. One of the compounds being investigated was tetrafluoroethylene.

One chemist at DuPont who was working on the project was named Roy Plunkett. Know him? He was once had a roommate named Paul Flory. One day Roy Plunkett opened up a brand new tank of tetrafluoroethylene gas, and nothing came out! He weighed it, and sure enough it was full. So he sawed the tank open and found a white powder where the gas was supposed to be. That powder, of course, was PTFE, polymerized from tetrafluoroethylene gas.

This is the kind of accident that makes science fun. There are kinds of accidents in science which aren't fun, say, those which involve large explosions and huge clouds of toxic gasses, but we won't talk about those right now. The fun kind of accident, which all scientists hope for, is an unexpected discovery which opens up a whole new area of investigation. This kind makes you famous and gets you lots of research grants, if you work at a university. If you work for a chemical company, it makes a lot of money for the corporate shareholders, and then you get to keep your job when downsizing time comes.

And then someday you might get your name mentioned in an educational website.

Source: **Roberts, Royston M.; *Serendipity: Accidental Discoveries in Science*; John Wiley and Sons; New York; 1989.**

Return to Level Two Directory

Return to Macrogalleria Directory

Mauricio Quintana
Houston, TX
4/2004

ATTACHMENT 2

UNDERSTANDING FIREARM BALLISTICS

Written and illustrated by
Robert A. Rinker

Basic to advanced ballistics, simplified, illustrated, and explained.

Fourth edition - expanded and revised.

Mulberry House Publishing ®

Clarksville, Indiana
U.S.A.

Understanding Firearm Ballistics

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So the title would better indicate the content, a title change was made with the 3rd edition (7th printing) from *Understanding Ballistics* to *Understanding Firearm Ballistics*.

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ACKNOWLEDGMENTS

In preparing this book, I have received invaluable help from numerous sources.

I obtained permission to reprint some material from an excellent magazine, *American Rifleman*, a publication of The National Rifle Association. Many thanks to Ron Keysor, who was the Managing Editor at the time.

Mr. William C. Davis, Jr. of Tioga Engineering Co., Wellsboro, Pa., not only gave his generous permission to reprint some of his work from the *American Rifleman*, he even corrected and revised one of the tables. Mr. Davis is highly qualified and his help is greatly appreciated.

With their kind permission, I have copied some facts published by Winchester/Olin Corp. Winchester is certainly one of the best and it is a pleasure to give credit where it is due. Also, a chart each is credited to the Federal Cartridge Co. and the Sporting Arms and Manufacturer's Institute. It is impossible to report on a subject as complicated as firearm ballistics without the research of the manufacturers.

I have made frequent mention of various government agencies and military ordnance groups. Their vast resources are invaluable in these areas of research. For an additional benefit, the results are generally available to the public.

In addition, a great deal of thanks to the readers of earlier editions who took time from their busy lives to write and suggest corrections about a few errors, such as spelling mistakes, grammar, etc. I was happy to notice that with their criticism, they still had many excellent comments about the book.

Furthermore, my deepest gratitude to the many magazine writers and editors who said such wonderful things about the earlier edition.

To all of these people and organizations, I wish to express my deep appreciation and thanks.

Robert A. Rinker

CHAPTER 14

BALLISTIC COEFFICIENTS, SECTIONAL DENSITY, and FORM FACTORS

Many people use ballistic coefficients in computations without understanding their function. This chapter should throw some light on the subject, even for those that are content to remain in the dark.

We will be discussing three subjects that are intermixed together. *Sectional density* and the *form factor* are included in the *ballistic coefficient*. It is important to mention that two of these items, the form factor and the ballistic coefficient, are both deceptive commodities that the average sportsman will be obtaining from charts rather than from testing on his own. They are both important because they relate directly to a projectile's ability to maintain forward velocity.

BALLISTIC COEFFICIENT

The ballistic coefficient is a measure of how well a bullet can overcome air resistance and maintain flight velocity. It is a number that is arrived at mathematically and **equals the sectional density of the projectile divided by its coefficient of form**. It can also be described as the ratio of the sectional density to its coefficient of form. It also is a ratio that compares the bullet to a standard bullet (projectile) that has been tested and therefore has known characteristics. The larger the number the more efficient. (*At this point, these terms may be confusing, but they will be explained in detail.*)

The ballistic coefficient of a projectile is necessary to a trajectory calculation. Bullets sold for use by hand-loaders have the ballistic coefficient in the manufacturer's data. For some unknown reason, this information is seldom available for factory loaded ammunition. Complete trajectory tables are available but ballistic coefficients for the bullets used are not. (Note; this may change in the near future, but it was true at the time this was written, including for this expanded version.)

A bullet's ability to retain as much muzzle velocity as possible is an important factor in both trajectory and game killing effectiveness. The ballistic coefficient possessed by the bullet will be a most important factor and the higher the number the better. **The three points that govern the ballistic coefficient are weight, diameter, and shape**. The first two can be used to create the sectional density.

As will be shown, there is a benefit in knowing this information and it can be determined for all bullets, even if they are hand-made.

It is well known that a bullet's design can affect the way it handles inadvertent tree limbs and also its stopping power in hunting and self-defense. The design also helps the aerodynamic aspects of the bullet. These

elements include the phenomena described elsewhere in this book as parasitic drag, bow wave, front air compression, and the partial vacuum at the rear of the bullet. The goal is to retain as much of the velocity as possible while using a bullet design that will do what the shooter wants it to do.

There are several discussions of kinetic energy in this book. Check the index and refer to them if needed. Remember two important points. (1) Kinetic energy is directly proportional to the mass of the moving object, a bullet in this case. For example, if their velocity is the same, a 100-grain bullet will impact at half the force as a 200-grain bullet. (2) Kinetic energy increases as the square of the velocity. For example, double the velocity of the bullet and the impact force will be increased four times. If the velocity is increased by three times, the impact force will increase by nine. Another way of explaining it would be to fire three bullets, all of the same weight, at 1,000 feet per sec., 2,000 feet per sec., and 3,000 feet per sec. The second will hit 4 times as hard as the first and the third 9 times as hard. If this is given some thought, it is impressive.

The ballistic coefficient measures the bullet's ability to conquer air resistance. Mathematically, it is the ratio between the sectional density and the coefficient of form. The higher ballistic coefficient is preferable, as the projectile will hold its velocity better. It is available in charts and can also be arrived at by formula. Generally, it is best to use the charts published by the manufactures because a good amount of test firing is required.

For custom bullets or any bullet that is not listed on a chart, the ballistic coefficient can be taken or estimated from a similar bullet. Simply use caution and pick a bullet close in caliber, shape, and sectional density.

The ballistic coefficient, when it is calculated from its form and nose shape, frequently works out different when it is test fired. We then have an *effective* coefficient that is more useful than the *paper* coefficient. The reasons for the inaccuracies in many paper ballistic coefficients are as numerous as there are misjudgments. The use of a different powder, load, or barrel can cause a bullet to fly differently and change the coefficient. The path through the air is frequently a very tiny helical (spiral) and rarely does it travel directly nose first. Shooting through screens or heavy paper will show us that bullets can wobble and this poor stability can be anywhere between the muzzle and the impact point.

The best values are always based on test shooting under laboratory conditions. No matter how it looks on paper, it takes very little to change the flight and alter the ballistic coefficient.

When a bullet's point is not changed, the ballistic coefficient will be raised by an increase in sectional density. The increase will usually enable the bullet to do a better job of holding its velocity. Although, in the interest of safe chamber pressure, the bullet with the lower sectional density may have a higher muzzle velocity and therefor a flatter trajectory. Notice that the

wording is "may have." Ballistics is full of variables that can change the outcome.

The ballistic coefficient contains both the sectional density factor and the coefficient of form (form factor). As mentioned, charts are the best source for this information.

The ballistic coefficient should not change as the velocity decreases down range. That appears logical because the velocity and the coefficient are separate. Unfortunately, when the ballistic coefficient is used in tables and formulas, it is only true if the projectile is exactly the same as the projectile in the table or formula. The difference may be slight, but it will be noticeable. If the curve is plotted on a graph, the two curves will not coincided exactly.

If this has all been too confusing, just remember that **the ballistic coefficient is the comparative ability of a bullet to push through the air and hold its velocity. It is a comparison to a standard by a multiplier.** Testing requires measuring the velocity drop over a known distance.

SECTIONAL DENSITY

Simplified, **sectional density is its weight divided by its cross-sectional area**. It is the expression used to describe the diameter of a bullet as compared to its weight. Stated in another way, it is the mathematical procedure that associates the mass of a projectile to its cross-sectional area. This is an important factor with the bullet's ability to sustain its velocity. Bullets with the most weight and the smallest diameters will have the higher sectional density. On the other hand, the less the bullet weight and the greater the diameter, the lower the sectional density. A heavier bullet has greater kinetic energy than a lighter bullet at the same velocity. A larger diameter bullet will have more air pressure build up at the forward end than one of smaller diameter. Therefore, the most proficient bullet will be the heaviest in proportion to its diameter. Of course, the easiest and most common way to make a bullet heavier and keep the same diameter is too make it longer.

One way to express this in plain terms is that sectional density is the weight that backs-up the bullet's diameter. If the bullet holds together, it will have greater penetration and more killing power. Sectional density is one of the bullet's most important characteristics, along with its shape, in maintaining velocity. It is easy to understand that a tennis ball will not proceed as strongly as a steel ball of the same size if they both have the same starting velocity.

On the other side, high sectional density will resist the push down the barrel more than low sectional density. It is just more weight for the expanding gases to accelerate to a required velocity. Therefore, the heavier bullet will have heavier recoil than the lighter bullet if they are both loaded to the same pressure. (Remember Chapter 6 about recoil?) It will take a larger cartridge and more powder to push the bullet to speed. A bullet of low

sectional density can be pushed to a higher velocity and a flatter trajectory for long-range use, but by the time the light bullet reaches the target, it may have little velocity and energy left. *Retained* velocity at impact may be too low for bullet expansion and penetration. (*Both covered in detail in Chapters 16-24-25-26.*)

MATHEMATICS - SECTIONAL DENSITY

Mathematically, sectional density is the ratio obtained by dividing the bullet's weight in pounds by the square of its diameter in inches. The bullet's weight in grains can be converted to pounds by dividing by 7,000. The area of a bullet's cross section increases with the square of the diameter. Therefore, we must square the bullet's diameter before it is divided into the weight. This is the usual method of computation, omitting the constant factor.

◆ $SD = W / d^2$

Where; SD = sectional density

w = bullet weight in pounds

d = bullet diameter in inches

For readers who like mathematics consider the **weight of the bullet in pounds divided by .7854 d^2, <u>or</u> $\frac{1}{4}\pi$ times the square of the bullet diameter.**

NOTES ON SECTIONAL DENSITY

◆ Air resistance is controlled by the cross-sectional area, which varies with the square of the diameter. Mass is what overcomes air resistance and it varies with the cube of the diameter. If you haven't been paying too much attention, one was *square* and the other *cube*. Consequently, with bullets that have the same properties, the ballistic coefficient will vary with the cube of the diameter divided by the square of the diameter, or simply with the diameter.

◆ A higher sectional density imparts a flatter trajectory for a particular muzzle velocity. Velocity loss adds to the flight time, and consequently its drop over a given distance. A bullet with low sectional density has a larger velocity loss, and it also has a greater bullet drop, and hence, a more curved and higher trajectory. This is based on equal velocity.

◆ The bullet with the bigger sectional density will hold velocity better down range but it may have a more arched trajectory compared to the lighter bullet, which probably had a higher velocity. Note that this does not contradict the item above, which is based on equal velocity. This item assumes the lighter bullet has a higher velocity than the heavier one.

◆ The higher the sectional density, the lower the muzzle velocities reachable with a given chamber pressure. This is one of the few points that are not favorable to high sectional density. The increased weight is harder to push to velocity without using or requiring more pressure.

◆ The greater the sectional density, the less velocity reduction after the bullet exits the muzzle. As explained in the last half of Chapter 13, bullets relinquish velocity because of air resistance. A bullet of high sectional density has a lower ratio of air resistance to momentum, so the loss of velocity is less.

◆ If the caliber (diameter) stays the same, then doubling the weight will also double the sectional density.

◆ The higher the sectional density, the less the projectile is affected by the wind. Chapter 20 explains *delay time* in detail, but briefly it is the difference between a bullet's actual flight time and its time if it had not lost any velocity. This is the main factor in wind deflection. High sectional density helps retain velocity and that in turn, reduces *delay time* and wind drift.

◆ Sectional density is strongly influenced by the bullet's length, but the jacket thickness, the alloy used in the core, the shape (as blunt nose vs. pointed); all are included.

◆ For equal bullet construction, the higher sectional density will have deeper penetration. This is due to increased momentum, greater velocity down range, and increased length to push in the expanded nose section.

◆ The greater the sectional density, the less velocity reduction after the bullet exits the muzzle.

BRIEF SUMMERY ON SECTIONAL DENSITY

This is an oversimplification, but we could state that a high sectional density lowers the internal ballistic performance inside the barrel. Outside the barrel, a high sectional density increases the ballistic performance.

COEFFICIENT OF FORM

The *coefficient of form* (also called *form factor*, *coefficient of bullet shape*, and *coefficient of reduction*) is a mathematical figure (a number or multiplier) of the bullet's shape, its smoothness and the shape of the base. In order of importance, shape is first. The advantage going toward the longer and sharper point and the shape from the tip back to the maximum diameter. The base has little importance on slow bullets but above the speed of sound the base becomes more significant. Smoothness has the least effect; due partly to the fact that few bullets are *rough*.

Form factors are always a comparison of one bullet's air resistance to that of another. It formulates the effect of different shapes on bullets with the same sectional density. Another way to express it, **the form factor compares the shape of the bullet in question to the shape of a standard bullet used in a particular ballistic table**. As you can imagine, it has limitations.

It must be emphasized that the form factor is for a particular ballistic table and not for use on any and all ballistic tables. In other words, a particular bullet may have one form factor for an Ingalls table and a different

one for C-1 charts and still another form factor for another chart. In other words, there is no such thing as an absolute form factor for any bullet.

Form factors cannot be calculated in the usual way. **No method is known to calculate and describe the shape in numbers suitable for use in formulas.** Firing tests are conducted for this purpose.

SAMPLE FORM FACTORS

These form factors are for examples only. Few will be exactly as listed, but in the absence of precise information for a particular chart, this should be a little help in showing how they are supplied. This is for basic knowledge only. For a form factor to be practical, it must be reasonably accurate and designed for the table being used.

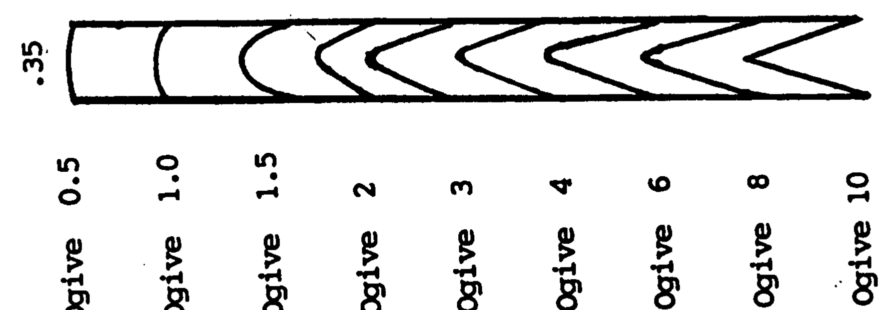
For more accuracy, subtract .06 for a boat-tail. Add .07 for a small exposed lead tip. If the exposed lead tip is large, add .20.

Very sharp profile	.60
Moderately sharp profile	.70
Moderately sharp profile with a small flattened tip	.85
Moderately blunt profile	1.00
Very blunt profile	1.20

There are several charts that can be used for estimating the form factor by comparison of the bullet's shape to the shapes shown on the chart. The DuPont Co. and others have worked out ballistic charts of this type. If the person using the chart takes the time and effort to do it correctly, the result can be reasonably accurate.

As just stated, the form factor is always for a particular table and based on the retardation of the standard bullet involved. Therefore, any chart of bullet shapes give in this text would probably not match a chart owned by the reader. A sample is given to show what they are like.

SAMPLE OF A BULLET SHAPE CHART FOR FORM FACTORS



Also, there are formulas available, but ordinarily they do not work as well as the charts and other methods. They also are difficult for anyone other than a math whiz. You say you want to see one anyway? Okay, here is a formula for ogival-pointed bullets.

$$C = \frac{2}{n}\sqrt{\frac{4n-1}{7}}$$

Where c = form factor

n = radius of the ogive curve in calibers

For the radius n, consider the .30-'06 that has a 2.1-inch radius, which is 7 times the diameter of the bullet. This means it has a 7-caliber radius. Putting 7 into the formula in place of the n, we arrive at figure of .56 for c, the form factor.

AIR RESISTANCE FORMULAS & TABLES

During the early history of ballistic research, many different ideas and methods were tried to compare projectiles by their drag resistance. All attempts tried to reduce it to a simple mathematical declaration. Many great thinkers of their time, including Sir Isaac Newton, worked hard on the problem. He said that the air resistance was proportional to the square of the velocity. This proved false for the velocities involved in almost all firearms. Later the decision was reached that a simple formula was not feasible.

Testing and experiment was determined to be the only answer. A single bullet of a certain size and shape was used as a standard and all the others were compared to it by velocity and deceleration. This standard projectile had a 2 caliber nose radius (ogival head) on a 3 caliber length. It was given a ballistic coefficient of 1.000 and all others were compared to it. It is still normal to use 3 decimal places for the figure. Russian Colonel Mayevski and a German named Krupp, created this particular standard in 1881. For all practical purposes, the constant multiplier called a ballistic coefficient was created at that time.

The Commission d'Experience de Gâvre of France conducted their firing tests in the late 1800's. In 1898, they published a report of their findings. They proved that air resistance could not be stated as proportional to the square of the velocity, as stated by Newton. They also said it could not be reduced to an easy formula. They published a table, which showed retardations for each velocity. This became familiar as the Gâvre function. It was excepted and sealed the end of the hunt for a single formula. From then on, **tables of actual values for each velocity, as discovered by firing tests, were used.**

U.S. Army Col. James M. Ingalls used Mayevski's research as a basis, and created his ballistic tables, which extend up to 3,600 f.p.s. First published in *Artillery Circular M* in 1918, and later with a few variations, his

tables are well known in the U. S. One set of his tables (No. 1) will compute the time of flight, the ballistic coefficient, and the velocity at a specified place in the trajectory, if the muzzle velocity and the velocity at some place in the trajectory is known. Another group of Ingalls tables (Table II) will compute the angle of departure for any range from the muzzle velocity and the projectile's ballistic coefficient. Other items of information can be computed from these charts, depending on what facts are available. Interestingly, the Ingalls tables were originally designed for use with cannons, where curved trajectories are very noticeable because of the extended range.

The British computed tables in 1909 that are about the same as Ingall's tables, except they go on up to 4,000 f.p.s. They are known as the Hodsock tables and were based on a spitzer bullet with a flat base.

Tables developed by the U. S. Army Ballistics Research Laboratory are more refined and use more recent data. In the 1930's, they conducted a huge amount of research into drag functions at the Aberdeen Proving Ground. They came up with their own tables for military use, which were based on the French tables and are known as G-function or G_1. (G for Gâvre) These tables give the connection between velocity and retardation. Knowing the shape and the velocity, the retardation may be found. The military also researched and produced tables known as G_2 for use on projectiles that, instead of the standard shape, had a long pointed nose and a boattail (tapered) base. It has also been known as J function and J tables. The U.S. military have several methods, which they use for their special long-range problems. G_5 is used for boat-tail bullets, which perform differently above Mach 1 than standard bullets.

A group of charts were produced by the engineers at the DuPont Company and published in 1926. Their numbers were for use in the *Ingall's Ballistics Tables*, which are used in the U. S. to calculate both velocity and trajectory. Col. J. M. Ingalls developed them.

The C_1 coefficient is another similar method based on the G_1 *drag law*. The ammunition manufactures use C_1 and it is used in almost all factory charts.

There have been many other different charts and tables published over the years. Of course, they are all approximate.

The charts and their proper use are not included here because of the room involved. To the reader not familiar with them, they appear to be an endless amount of pages filled with columns of numbers. Some charts require the use of high mathematics and for others, the math. is easier. For the most part, they enable us to predict, based on the muzzle velocity, what the velocity would be at any other point as the velocity decelerates. This is based on the retardation created by air resistance. Of course **time** is a major factor as is **space** - the space being the space passed over by the projectile as its' velocity is slowing. (In this case, it is usually called space, although

◆ A high ballistic coefficient is vital in reducing wind deflection. The time lag discussed is a result of atmospheric drag and the ballistic coefficient measures how well a bullet performs against drag. The result is that a high ballistic coefficient will have less wind deflection, all else equal.

◆ An increase in bullet weight will also increase the ballistic coefficient but it will also lower muzzle velocity, if all else stays the same.

◆ There are always compromises. A game bullet must be effective on game, even if it gives up some trajectory qualities in favor of stopping power.

◆ The ballistic coefficient is as important as velocity and easier to upgrade. If the average cartridge case is lengthened by .200", the velocity will only increase 2% or 3%. Instead, add the .200" to the length of the bullet's head and the ballistic coefficient jumps by 35% to 40%.

◆ A bullet with a high ballistic coefficient will spend less flight time over a given distance, all other factors being equal, so it will have less wind deflection. The lag time from drag will be less. A higher ballistic coefficient brings a flatter trajectory and more velocity and kinetic energy delivered to the target. A higher ballistic coefficient will have a lower form factor. A higher bullet weight will increase the ballistic coefficient.

◆ Bullets with identical ballistic coefficients, fired at the exact same velocity, will always have exactly the same trajectories.

◆ The ballistic coefficient is directly proportional to the sectional density if the bullets have the same shape.

◆ For the utmost accuracy, it would be necessary to create and use a ballistic coefficient that changed with velocity changes.

◆ The ballistic coefficient is a simple multiplier.

◆ A bullet with a lower ballistic coefficient, as compared to a higher one, will have a slightly more arched trajectory, a lower velocity and lower energy delivered downrange. The energy loss will be, in most cases, more pronounced than the other two.

FOUR MAIN POINTS (from above)

1. Decreasing the form factor (streamlining) will increase the ballistic coefficient for a given bullet weight and caliber.

2. The higher the ballistic coefficient for a given weight, the flatter the trajectory, the less wind deflection and the higher the velocity and kinetic energy at a specified range.

3. Increasing the bullet weight will increase the ballistic coefficient for a given caliber and form factor (shape).

4. When we increase the ballistic coefficient of a projectile of a given weight, we also increase its energy and velocity at any given down range position, we flatten its trajectory, and we reduce its wind deflection for a given wind condition.

MATHEMATICS

Air resistance is based mostly on the cross-sectional area of a bullet, which in turn varies with the square of the diameter. Mass is one of the main things which will defeat air resistance and it varies with the cube of the diameter. For readers not paying attention, they were both different. The first was based on the square and the latter on the cube. Therefore, for bullets with the same comparative proportions (not properties), their ballistic coefficients will vary with the cube of the diameter divided by the square of the diameter. This mathematically brings us back to the same diameter we started with. So, a .25 caliber bullet with the same shape as a .50 caliber bullet will have a ballistic coefficient of half as much. So, with bullets of different calibers but of similar shapes fired at similar velocities, the ballistic coefficient will be proportional to the weight divided by the square of the diameter. This will be in ratio to their diameters. (If that gobbledegook was confusing read on and it will become easier. If necessary, reread this paragraph.)

◆ There are two basic formulas for determining ballistic coefficients under standard conditions. The second formula is the more accurate and the one used the most.

$$C = SD / i \qquad \text{also} \qquad C = w / i\,d^2$$

Where: C = ballistic coefficient
i = form factor from bullet's shape
SD = sectional density
w = bullet weight in pounds
d = diameter

Example of 2nd formula: bullet weight 200 grains + 7000 = .02857 grains, diameter .308 inches, form factor .75.

$$\mathbf{.02857 / (.75)(.308)^2 = .40155 \text{ or } .40}$$

The form factor (i) can be stated as the ratio of the drag coefficient of a standard bullet to the drag coefficient of the bullet in question. With all bullets being different in shape, size, and weight, they will all have different numbers than the standard. (No one said this was going to be easy.)

The form factor in various formulas is designated as i, as n, and as c. The use of c can be confused with the C that is normally used to designate the *ballistic coefficient*. While the use of c or C is common, here we are using i because there is less chance of confusion.